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A Systematic Literature Review of the Supply Chain Operations Reference (SCOR) Model Application with Special Attention to Environmental Issues

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Abstract. Present day concerns with climate change have imposed the consideration of green practices as a competitive requisite for supply chains. Consequently, it is increasingly mandatory for business organisations to make a transition toward integrating environmental performance as a constituent element for success. With its Green SCOR component, the SCOR model, which is a diagnostic tool for supply chains, can serve as a strategic tool for such environmental performance. However, evidence of environmental considerations in the application of the model within an array of industries in the last decade has not been investigated. This article uses a number of SCOR assessment criteria and elements to review selected SCOR model application papers, published between 2000 and 2012 with special attention to environmental criteria. Results indicate that although the innovative paradigm of moving from single firms to supply chain outfits has been embraced by business organisations, no paper experimented the model based on an end-to-end supply chain approach. While a generally timid interest in the model was observed, annual distribution of the articles shows a positive trend in the number of environment and return process related papers. 11.1% of the papers attempted the environmental dimension of the model while 24.4% attempted the return process. The study notes that while the SCOR model is suitable for supply chain financial performance evaluation, it is also a practical decision support tool for environmental assessment and competing decision alternatives along the chain.

Keywords: SCOR model, supply chain management, environmental performance, enterprise engineering.

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1. Introduction

The effects of climate change have imposed the consideration of green practices alongside the financial performance of business processes as a competitive requirement in the global market. Consequently, it is increasingly compelling for traditional supply chains to make a transition toward integrating environmental performance as a constituent element for their value adding processes and organizational success (Gifford, 1997; Hwang *et al.*, 2010, Walton *et al.*, 1998). While several concepts and modelling frameworks have been developed to improve supply chain performance, the characteristics needed by its partners to understand the mechanics and processes of the supply chain are mandatory in the model development process. Amongst the existing models in the literature (e.g. the GSCF – Global Supply Chain Forum framework (Lambert *et al.* 2005) or the Process Classification Framework (PCF) from The American Productivity and Quality Center (APQC, 2013), the Supply Chain Operations Reference (SCOR) model (SCC, 2010), is considered by some scholars (e.g Huan *et al.* 2004; Hwang *et al.* 2010; Zangoueinezhad *et al.* 2011) as the most promising for strategic decision-making and the most rigorous for supply chain performance evaluation. The model maximizes supply chain visibility including efficiency, measurable and actionable outcomes when the visibility strategy of the supply chain is aligned with the SCOR model. The first effort of the SCOR model to take environmental concerns into account was the introduction of the *Return* process in its early version. With its recent extension to include GreenSCOR, it is gradually being applied in the natural resource management field and for the environmental performance of supply chain processes (Schnetzler *et al.*, 2009; Bai *et al.*, 2010; Hwang *et al.* 2010; Bai *et al.* 2012; Xiaoa *et al.*, 2012).

1.1. The SCOR model

The SCOR model is a diagnostic tool for Supply Chain Management (SCM) that enables users to understand the processes involved in a business organization and to identify the vital features that lead to customer satisfaction. Under construction since 1996, the template was initially developed by PRTM; a management consulting firm, now part of PricewaterhouseCoopers LLP (PwC). It was later endorsed by the Supply Chain Council (SCC), an independent and nonprofit organization and its affiliated members as a cross-industry de facto standard diagnostic tool for supply chain management.

Today, the SCC has published its eleventh version. Figure 1.1 illustrates the SCOR model and its management processes.

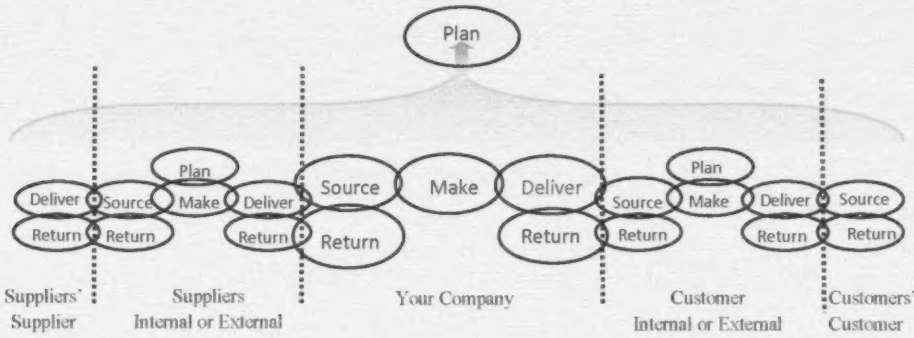

Figure 1.1: Schematic representation of SCOR management processes (Adapted from SCC, 2010)

SCOR is organized around five management processes (*Plan, Source, Make, Deliver*, and *Return*) that are further subdivided into process categories, elements, tasks and activities (Huang *et al.*, 2005; Hwang *et al.*, 2010; Kasi, 2005; Schnetzler *et al.*, 2009; SCC, 2008). According to Li *et al.*, (2011), SCOR enables companies to examine the configuration of their supply chains. It also identifies and eliminates redundant and wasteful practices along supply chains. As a business process architecture, it defines the way these processes interact, how they perform and how they are configured from a supplier's supplier to a customer's customer (Min and Zhou, 2002; Huang *et al.*, 2005; SCC, 2010). The GreenSCOR extension of the model was first introduced in its fifth version. Cheng *et al.*, (2010) and Schoeman and Sanchez (2009) note that, GreenSCOR is a modification that integrates environmental considerations through processes, metrics and best practices into SCM processes, while taking into account the impacts of operations at each stage of the product life cycle. However, our literature search reveals that focus on the SCOR model research is primarily on its financial component.

The application of the SCOR model has been reported in the following industries to name a few: the lamp industry (Vanany *et al.*, 2005), transistor-liquid crystal display (Hwang *et al.*, 2008), the ethanol and petroleum industry (Russel *et al.*, 2009), geographic information systems (Schmitz, 2007), the construction industry (Cheng *et al.*, 2010; Pan *et al.*, 2010), automotive industry (Potthast *et al.*, 2010), the professional services industry (Ellram and Billinton, 2004), the wood industry (Schnetzler *et al.*, 2009), information technology and technology consulting

(Dong *et al.*, 2006), the tourism industry (Yilmaz and Bititci, 2006) and shipbuilding (Zangoueinezhad *et al.* 2011). With a wide range of the SCOR model application already reported in supply chain optimization (Bolstorff and Rosenbaum, 2003; Cai *et al.*, 2009; Huan *et al.*, 2004), SCC (2010) notes that the model also provides a foundation for environmental accounting in the supply chain. Paradoxically, research combining green performance evaluation and the SCOR model has remained rare (Hwang *et al.*, 2010). Consequently, Dutta, and Westenhoefer (2008) conclude that there is little evidence associating the application of the model with environmental performance. While Huan *et al.*, (2004) consider SCOR as a rigorous tool for the evaluation of supply chains, Reyes and Giachetti (2010) claim that its popularity is limited as it merely reflects the practices of stronger economies.

The objective of this paper is to provide supply chain researchers and managers with baseline information on the industry applications of the model with special emphasis on environmental considerations. A critical analysis of recent application papers of the model, published in the last 13 years is conducted and research gaps identified. This is a unique synthesis, as we did not find any similar review of SCOR applications during our literature search.

This paper is organized as follows: Section 2 briefly presents the key questions addressed and the approach for the literature review. Section 3 presents the results subdivided into three parts: Part one reviews environment related papers. Part two reviews other papers based on the different research methodologies applied while part three identifies research gaps and presents the findings. Finally, Section 4 outlines the conclusions and recommendations for future research initiatives.

2. Materials and methods

This review is carried-out to survey the industrial applications of the SCOR model published in peer-reviewed papers between 2000 and 2012. Subsequently, our results are presented using qualitative and quantitative evidence.

2.1. Questions addressed

The main questions addressed by the present review are:

1. Which research methodologies are employed by the authors?

2. What are the key findings?

3. How are the various SCOR elements addressed in the papers?

4. What proportion of the papers address the environmental component of the model?

5. Are any particular interests expressed in the different SCOR management processes?

6. What are the principal research gaps after more than a decade of development and application of this reference model?

2.2. Article search and selection procedure

A search of the ABI/INFORM global database, Google Scholar, SCOPUS and the ISI Web of Science search engines yielded a number of papers each with several of them appearing in more than one search engine. In order to allow an in-depth analysis of each article, we narrowed our choice to 45 full-length peer-reviewed papers dealing with the SCOR modelling framework and cutting across a spectrum of industrial applications. In order to obtain first-rate articles from the lot, the selection exercise was guided by the following criteria: 1) Must be a scientific article, published in a peer-reviewed journal. 2) Dealing with the SCOR model application. 3) Article not older than the year 2000. Since the GreenSCOR component of the model was developed in 2002 and introduced into SCOR version 5.0, the base year for the articles was limited to 2000. Our purpose was to have the maximum possible number of GreenSCOR-based articles for the review exercise. An appraisal of the scientific contribution of each article was conducted taking into account the SCOR management components. In order to meet the requirement for scholarly review of the papers, the dual approach to literature review (Kekäle *et al.*, 2009) was employed. It requires a synthesis of each paper, followed by a critical analysis of its content including the theories and methodologies that are employed.

Characterization and gap analysis took into consideration article distribution by author(s), journal, year of publication, methodology applied, environmental concerns, SCOR components and management processes. A number of SCOR-based criteria assessment elements were developed into an evaluation framework for critical analysis of the research gaps. Table 2.1 provides detailed information on the assessment criteria elements that were used.

The framework applied three assessment standards (category, criteria and article content) for the evaluation exercise. The SCOR items that were selected were those that provided

greater insight to the general understanding of the SCOR model application. A synthesis of the findings was presented and interpreted under section 3.

Table 2.1: Definition of assessment criteria elements used

Category	Criteria	Definition
General Information developed by Santa-Eulalia *et al.* (2012) based on Shapiro (2000)	Inter-temporal dimension	Time-based supply chain decision levels, including strategic, tactical, operational and execution decision-making levels.
	Spatial dimension	Geographic layout of supply chain units, i.e. vendors, facilities, clients and customers
	Functional dimension	Procurement, manufacturing, distribution and sales.
SCOR Characteristics	Processes	The five management processes of the SCOR model
	Performance attributes	A combination of metrics for setting strategic direction of supply chains
	Metric Level	A hierarchical configuration of the SCOR model performance evaluation process
	Process types	Made-up of Plan, Execution and Enable. They are pprocess categories assigned to planning support to the allocation of resources to expected demand, plus process categories triggered by current or planned demand and process categories that serve as support to the other processes
	Supply chain strategy	It is the decoupling point of a product which can be MTS (Make-to-Stock), MTO (Make-to-Order) or ETO (Engineer-to-Order) product.
	Practices	Best practices and Leading practices which are conducts that are applied to safeguard supply chain performance
	Return	A process of planning, implementing and controlling the inbound flow of defect or excess products to either recover value or ensure proper of disposal.
	SCOR version	The different periodical releases of the SCOR model.
Application information	Modelling Software and technology	Interoperability of the conceptual characteristics of the SCOR model with other tools to provide modelling clarity and increased capabilities.
	Industry sector	Field or domain in which the SCOR model is applied.

The general information section on Table 2.1 is based on the model developed by Santa-Eulalia *et al.* (2012). The authors develop a distributed planning analysis (DPA) model using supply chain integration concepts by Shapiro (2000) that can be translated into a multi-agent society. The DPA identifies the possible supply chain planning, scheduling and control functions at different levels of a typical supply chain. They equally introduce a new level (the decision dimension) to complement the three by Shapiro (2000). These autonomous supply chain entities are then built-up into a model known as the supply chain planning and scheduling cube where they can interact with one another.

3. Results

3.1. Article characterization based on environmental considerations

According to Seuring and Muller (2008), the environmental cost of production should come in line with the value of the product. It is thus essential to introduce such cost into the business model of a supply chain to avoid undervaluation and price deflation of products. Our first objective was therefore to assess the contribution of the application papers in establishing the link between environmentally conscious business practices and supply chain performance. However, out of the 45 papers that were reviewed, only five (Schnetzler *et al.*, 2009; Bai *et al.*, 2010; Hwang *et al.*, 2010; Bai *et al.*, 2012; Xiaoa *et al.*, 2012) attempted a green performance evaluation of the SCOR management processes while 11 attempted the return process. The five environment-related papers and 11 return process papers are analysed below.

The applicability and the environmental benefits of the SCOR model in the Swiss forestry sector are investigated by Schnetzler *et al.*, (2009). The authors examine whether the second level of the model can be standardised and used for the description of the wood supply chain. Standard SCOR process elements are modified to involve harvesting, delivery, and forestall planning. The study impinges on the *Source* process, taking into account specific management practices that influence tree growth in plantations. While the *Make* process is translated into wood harvesting activities such as felling, delimbing, debarking, cutting, hacking, sorting of logs and skidding, the authors consider the *Return* process as irrelevant in the forest value chain.

A second paper (Hwang *et al.*, 2010) illustrates the importance of green purchasing among green label products manufacturers in Taiwan. The authors portray green purchasing as a useful tool for the mitigation of environmental impacts of consumption and for the promotion of clean production technology. A link between the Deming cycle (the plan-do-study-act cycle of green purchasing) and the SCOR sourcing process as well as its performance metrics is established using a structural equation model of 13 hypotheses. The relationship also reveals that under green purchasing, overall corporate performance can be improved if the environmental performance of suppliers of the chain is evaluated.

In Bai *et al.*, (2010), rough set theory (a mathematical tool for the analysis of data from a broad set of measures) is applied for joint ecological and business performance measurement

of supply chains. The authors apply a three stage process consisting of supplier selection, evaluation and development using three separate rough set theories in green supplier management. Rough set methodology is depicted as a flexible application for supplier selection, performance measurement evaluation and programme development evaluation. The article also illustrates that green performance measurement of suppliers can be accomplished using a neighbourhood rough set with two factors: distance and a threshold value. Business and environmental scores are used as decision attributes to determine the performance of each supplier. The rough set methodology is consequently recommended to decision makers for the performance evaluation of their suppliers.

Xiaoa *et al.*, (2012) apply the SCOR model to construct a standardized closed-loop logistics operation reference model. The model provides supply chain managers with general analysis on the profit function and decision-making on potential risks within forward and reverse logistics. The authors demonstrate that in green logistics operation, all logistics processes form a bidirectional closed-loop topology within which, all materials are regarded as resources that can be repeatedly used through recycling loops. Such recycling loops help in improving resource use efficiency and reduction of environmental resource exploitation.

Bai *et al.*, (2012) integrate grey systems theory (a concept for solving problems in systems with poor or incomplete information) elements with neighbourhood rough set theory to improve the environmental performance of supply chains. The authors apply the SCOR model to determine core sets of environmental and business performance measures for supply chain sourcing based on historical and external (to the supply chain) outcomes. The SCOR-based sourcing function performance measures are based on five dimensions (cost, time, quality, flexibility and innovation). The methodology helps to evaluate, select, and monitor sustainable supply chain performance measurement that can be integrated into a performance management system.

Although environmental concerns are treated in the five application papers described above, the review observes a predominantly theoretical submission, i.e. one case study, one simulation and three conceptual papers. The return process is also discussed in 11 other papers although they lay emphasis solely on the financial implications of supply chains.

Stephens (2001) describes the return process as presented in the SCOR template while Lambert *et al.* (2005) present its significance and outline the different activities involved in the

execution of the process. Mclaren and Vuong (2008) consider the Return process as a functional attribute that provides support for primary supply chain processes, data management, decision support, relationship management, and performance improvement.

Rabelo *et al.* (2006) demonstrate how the manufacturing facility handles the sourcing of returned defective products (SR1), the sourcing of maintenance required operations (MRO) for sold products (SR2) from all local warehouses, and the delivery of MROs back to warehouses (DR2). The warehouse and service facilities handle the sourcing of returned defective products (SR1), the sourcing of MROs for sold products (SR2) from customers, and the delivery of MROs back to customers (DR2). In another simulation, Stavrulaki and Davis (2010) note that within the Build-To-Stock and Assemble-To-Order supply chains, the return management philosophy is based on centralised processing that is efficiency-driven while in a Make-To-Order and Design-To-Order supply chains, the return process is based on decentralised processing that is customer service driven.

Li *et al.* (2011) extend the Return process by integrating quality assurance measures into the process. Variables relating to the process are analysed and it is observed that reliability and responsiveness are important quality indicators for the process. Two hypotheses on supply chain return decisions are used in testing the process and a number of decision constructs retained. The authors observe that the process has a positive impact on customer facing supply chain quality performance and internal facing business performance. Within the construction material supply chain, Pan *et al.* (2011) examine steel bars, concrete and steel tendons that are disqualified and disposed as waste. Qualified and disqualified steel bars are determined using discriminant analysis probability. The C260 steel bar incoming acceptance report indicates a defect occurrence probability of 0.00001 that is recycled. In another paper, Xiao *et al.* (2012) demonstrate that all logistics processes form a bidirectional closed-loop topology. They integrate the return process with forward logistics and focus on non-conforming products, customer recovery and other products generated in the forward logistics. The process is composed of aspects such as recycling, sorting, cleaning, purification, maintenance return, re-packaging processing, re-using and waste disposal.

The review also observes that despite the importance of all management processes in environmental performance evaluation, authors showed more interest in the SCOR sourcing process. None of the studies also proposed a mechanism for addressing or improving the

environmental performance of supply chain processes. There is need for a practical approach that safeguards against environmental concerns along the different value adding processes of supply chains.

3.2. Article characterization by methodological considerations

This section is subdivided into five subgroups, based on the methodological approaches that were applied by the authors. They are examined under conceptual methodology, case study, simulation, survey and other empirical methods (exploratory and the Delphi).

3.2.1. Conceptual papers

Stephens (2001) presents the first SCOR model publication that describes its development and application; the five management processes and their hierarchical configuration are studied. In furtherance of the latter study, a supply chain model for tracking performance using causal relationships between SCOR metrics is developed by Ganga and Carpinetti (2011). The authors apply fuzzy logic to deal with problems of uncertainty and subjectivity within the supply chain by predicting performance using SCOR levels 1 and 2. Statistical analysis of the prediction model results confirm the relevance of the causal relationships embedded in the SCOR model. The results also strengthen the claim that the adoption of a prediction model based on fuzzy logic and on metrics of the SCOR model is a feasible technique that can help managers in the decision making process of supply chain management. In a similar study, Theeranuphattana and Tang (2008) apply an existing fuzzy set measurement algorithm by combining the strengths of the SCOR model and Chan and Qi's measurement algorithm to develop an empirical and efficient measurement model for resolving problems of supply chain performance. Ashayeri *et al.*, (2012) present an intuitionistic fuzzy Choquet integral operator based approach that allows interactions, correlations or dependencies among decision making criteria to select supply chain partners and configuration in order to increase value within the chain. The authors apply the SCOR model to structure the supplier selection process. Sensitivity analyses are also conducted to determine the evaluation results of the sensitiveness of configurations to the criteria weights. Optimization and coordination of activities through information sharing is considered as a main philosophy of the SCOR model. Khoo and Yin (2003) propose an extended graph-based virtual clustering-enhanced technique for simplifying

and optimizing supply chains. It is done by modelling a complex supply chain with multiple level assemblies comprising geographically distributed suppliers, warehouses, factories, distribution centres, transportation and customers.

Another network optimization model by Huan *et al.*, (2004) integrates SCOR performance metrics and Analytical Hierarchy Process (AHP) while Stavrulaki and Davis (2011) use a conceptual model to expound the need for alignment between key aspects of a product and its supply chain processes including the links between the processes and supply chain strategy. The authors demonstrate that products can be produced with one of four supply chain structures: make to stock, assemble to order, built to order and design to order. They also substantiate that the suitability of each structure for the various products depends on their demand characteristics. The study reveals that every supply chain structure determines its production and logistics processes depending on its strategic priorities. In a related study, an extended reference model covering the SCOR process map is proposed by Milleta *et al.*, (2009) to describe all physical and informational dependencies, in a multi-view of business process mapping. The authors notice that existing alignment risks neglecting important process dependencies within a business process management and enterprise. They also analyse individual SCOR items according to their existing degrees of standardisation. James (2005) uses a three phase systematic methodology involving SCOR-built supply chain typology analysis, performance analysis and operations model design for the efficient exploration and design of the SCOR model. Clivillé and Berrah (2012) use MACBETH methodology (a multi-criteria approach) to illustrate the processes and overall performance of a principal manufacturer within a supply chain. The overall performance of the supply chain is identified by combining the performances of other supply chain partners plus integrating the performance of an impacting supplier into the prime manufacturer's performance. A risk factor analysis model is also adopted in which, risk sources are divided into six types (people, facility, materials, law, information and environment).

The SCOR model is tested in another study alongside four other models by Lambert *et al.*, (2005) to identify the most appropriate for supply chain management (SCM) while Ellram *et al.*, (2004) assess the applicability of the SCOR model together with two product-based manufacturing models: the Global Supply Chain Forum Framework and Hewlett Packard's Supply Chain Management Model. Potthast *et al.*, (2010) use six SCOR-based standard

logistics sourcing models to conceive a user friendly decision support system for the sourcing component. The models which are divided into three distinct features: sourcing with stock-keeping by the customer, sourcing with stock-keeping by the supplier or service provider and sourcing customer-order-related (without stock-keeping) model in which the supply chain has no warehouse buffer between the supplier and customer to reduce cost and improve the logistic performance of an automotive industry. A sourcing model is nonetheless based on the principle of continuous flow production in which the supplier's production is synchronized according to the customer's production demand, amount and the time he is ready to wait for his command.

Elgazzar *et al.*, (2012) apply the Dempster Shafer-AHP model (a mathematical theory of evidence for multi-criteria decision-making that improves traditional approaches to multi-criteria decision modelling) to develop a performance measurement method that links supply chain process performance to a company's financial strategy. Authors highlight the relationship between supply chain process performance and a company's financial performance. A Supply Chain Financial Link Index (SCFLI) is also developed to test the link between supply chain process performance and a company's financial strategic objectives. Wang *et al.*, (2010) combine Business Process Reengineering (BPR) and SCM to conduct a comparative analysis of post and pro-performance indices as a basis for business process modification for assessment of SCOR model top-down approach. The authors discuss the limitations of current SCOR analysis and provide a mapping technique based on cause and effect, the SCOR Standard, and Mutual Solution for gap mapping, problem prioritization, and business process modification in a supply chain setting. A panoramic description of the SCOR model is offered by Huan *et al.*, (2004) in which its strengths and weaknesses are analysed, and methods of application discussed. Zdravkovic *et al.*, (2011) apply a value chain method to compare the performance measurement of manufacturing and tourism industries. The scope of research of the SCOR model is extended by developing a conceptual model for the industry. The authors identify the competitive requirement summary of the planning process of the industry is identified while that of level 3 is presented with a number of process details given by work streams.

Irrespective of the methodological configuration however, most papers (Bai *et al.*, 2010; Hwang *et al.*, 2008; Hwang *et al.*, 2010; Li *et al.*, 2011; Potthast *et al.*, 2011) emphasize the importance of the sourcing function in supply chain performance. This section summarizes

major contributions and provides various theoretical approaches that can be used in the application of the template. They also provide useful information on the importance of the conceptual approach to supply chain problems.

3.2.2. Case study methodology

This section seeks to understand and to highlight approaches that have been applied in the operationalization of the SCOR model. It also throws light on case study outcomes and the key contribution of each paper to supply chain performance improvement in the last decade.

Han and Chu (2009) assess the relative effectiveness of the collaborative supply chain operations reference model using a regional electricity industry in China. It extends the SCOR model by integrating collaborative product commerce and project management to propose a comprehensive collaborative supply chain operations reference (CSCOR) model consisting of four hierarchical levels: business, cooperative, process and operational models. Still within the collaborative context of supply chain operations, Cheng *et al.*, (2010) present a case study example on the modelling of construction supply chains using the SCOR model in the mechanical, electrical and plumbing processes of a construction project. The authors present a model-based service oriented framework termed, the Supply Chain Collaborator in which each supply chain process element is implemented as a discrete web service component. They argue that representing supply chains using a network model can help understand the complexity, support reconfiguration, bottlenecks identification, prioritization of company resources, as well as value addition to the management of construction supply chains.

Persson (2011) equally develops a simplified method for analysing a supply chain through the introduction of a new building block-the metric module. This development provides a more comprehensive SCOR template for capturing the dynamics of supply chain operations. In another study, the balanced scorecard and SCOR model are combined by Thakkar *et al.*, (2009) to propose a comprehensive and integrated supply chain performance measurement framework for small and medium size enterprise clusters in India based on qualitative and quantitative views. Other authors Irfan *et al.*, (2008) develop a SCOR-based supply chain flow synchronization of Pakistan's tobacco industry that presents key challenges, SCM efforts, and opportunities in the physical, information and financial flows of the chain. Burgess and Singh

(2006) fashion an integrated supply chain analysis framework by means of the grounded theory (an inductive research method that moves from specifics to generalizations). They use the SCOR template to develop the framework for analysing supply chains within a multi-disciplinary and multi-method research paradigm in an Australian public utility industry. Key actors within the chain are identified and interviewed for insights into the social and political factors that determine supply chain performance. Soffer and Wand (2007) limit their investigations to the delivery decision area of the SCOR-model. An analysis of delivery activities for the Make-To-Order manufacturing strategy finds that customer order, payment schedule, product, shipping documentation, product receiving and verification are key performance metrics.

This review section establishes that the SCOR model is practical and can be adapted in different contexts. The case study approach can be used in extending the SCOR model as well as verifying the suitability of developed models. The application domain of the template is equally wide ranging.

3.2.3. Simulation methodology

The authors focused on System Dynamics, Discrete Event and Hybrid Simulation techniques to attain their objectives. Some SCM studies (Röder and Tibken, 2006; Rabelo *et al.*, 2007; Persson and Araldi, 2009) apply system dynamics, discrete event simulation and hybrid simulation models to examine various configurations within the chain and what-if scenarios. Gulledge and Chavusholu (2008) and Huang *et al.*, (2005) use the simulation technique to automate the SCOR model as an enabler for process-oriented supply chain business intelligence. They prove that automated support for key performance indicators (KPIs) is feasible and achievable but difficult if data collection to support KPI construction is not automated.

The simulation of a specific level of operation in a supply chain (Persson and Araldi, 2009) reveals that all companies share the same set of processes in SCOR level 3. The authors develop a comprehensive tool that integrates SCOR and an ARENA discrete event simulation for understanding static operations. The tool equally helps a supply chain analyst to understand such dynamic effects of the chain as variations in the rate of production and raw material quality. Guruprasad and Herrmann (2006) also develop a SCOR-based hierarchical approach to

simulation modelling for forecasting supply chain performance. The framework enables the construction of simulation models with discrete event simulation.

A simulation decision support system using a modular modelling concept for intra and inter-company process is developed by Röder and Tibken (2006). The system evaluates different configurations of process chains with different sets of parameters on material and information flows. Pan *et al.*, (2010) combine the case study and simulation methods to enhance the performance evaluation of construction supply chains using a SCOR performance evaluation system. The authors use a bridge construction project to develop a hybrid dynamic modelling methodology for the construction industry through computer simulation. The manufacturing activities and services of the global supply chain of a multinational construction equipment corporation are modelled through the integration of the AHP technique, system dynamics and discrete-event simulation by Rabelo *et al.*, (2007). With the aid of the SCOR template, the authors develop models that enable managers to evaluate competing decision alternatives and other qualitative factors within the supply chain. The performance metrics of the SCOR model are simulated by Tang *et al.*, (2004) based on an IT methodology of three analytical techniques (SWOT analysis, value-chain analysis, and quality function deployment technique that transforms user demands into design quality) and four levels of analysis: strategic, process focus, people and technology.

In addition, a framework for avoiding SCOR model semantic inconsistencies and incompleteness is developed by Zdravkovic *et al.*, (2011) in the knowledge management of supply chain networks. The paper describes a literal web ontology language of SCOR concepts and expands the model application domain. Pan *et al.*, (2011) construct a hybrid model to study supply and demand behaviour. The authors apply the SIMPROCESS dynamic simulation software to assist in establishing a hierarchical model that explores the behaviour of the construction supply chain process.

Inferring from the above simulation based papers, it can be concluded that the integration of system dynamics and discrete-event-simulation models can enable the modelling of the value chain and the illustration of simulation results for profits, customer satisfaction and value chain responsiveness. Despite the ease and cost effectiveness of simulation models and the vital roles they play in supply chain management such as improving optimization and enabling

an integrated supply chain management, search results reveal a comparatively limited number of papers during the study period.

3.2.4. Survey methodology

Li *et al.*, (2011) use survey data from 232 ISO 9000 certified companies to extend the five decision areas (*Plan, Source, Make, Deliver*, and *Return*) of the SCOR model by incorporating quality assurance measures in the supply chain process. While the results reveal that the decision areas positively and individually influence both customer-facing supply chain quality performance and internal-facing firm level business performance, *Plan* and *Source* decisions show a greater positive effect on customer-facing supply chain performance (reliability, response, and flexibility), while *Make* decisions are more influential on internal-facing performance metrics (cost and asset). The authors propose an approach for operationalizing the SCOR model while a list of critical supply chain operations metrics is presented. Based on the results, causal relationships between supply chain process decisions and performance are developed. The authors also apply a factor analysis approach that examines the underlying patterns for a large number of variables and regression analysis to test hypothesised relationships. The stepwise regression technique is applied by Hwang *et al.*, (2008) to investigate sourcing processes and their performance metrics through an analysis of the dependency of measures. The authors employ the questionnaire survey technique to collect empirical information on the application of the regression model to examine the level 2 SCOR sourcing process and its performance metrics in a Taiwanese thin film transistor-liquid crystal display industry using SCOR version 7.0. A time-based supply chain performance assessment tool for key activities using two SCOR performance dimensions (cost and reliability) for Taiwanese small and medium size enterprises is developed and tested by Banomyong and Supatn (2011). Results from McCormack (2008) indicate a highly significant statistical correlation between supply chain maturity and performance. Their results portray the *Deliver* process maturity as having a higher impact on the overall performance when compared to the other supply chain processes.

While the survey research approach may be termed subjective, since it limits data collection to a selected portion of the population, the authors effectively applied the method in assessing and setting supply chain needs and goals.

3.2.5. Other empirical methods

Other empirical methods that were observed in the review included the exploratory and the Delphi methods. Within the exploratory design, Lockamby and McCormack (2004) use regression analysis to investigate the causal relationships between process management and supply chain performance. The authors develop four SCOR decision areas to characterize supply-chain management practices and processes and determine those that have the most influence on the chain's performance. Based on a study of 90 firms and 523 individuals within eleven industry sectors, the authors observe that planning processes are central in all SCOR supply chain planning decision areas while collaboration is the most important in the *Plan*, *Source* and *Make* planning decision areas. In another study, McLaren and Vuong (2008) apply grounded theory to conceive a classification for the description of functional attributes. A total of 83 functional attributes of five top level supply chain categories that include primary supply chain processes, data management, decision support, relationship management and performance improvement are classified. The authors identify causal relations through research reports and vendors' documentation. Both papers provide baseline information and insight that can contribute to SCOR model research.

The Delphi method of forecasting (*A* method based on the results of several rounds of questionnaires referred to a panel of experts who interact incognito, and arrive at a consensus based on their independent analyses) is another method used by Reyes and Giachetti (2010). The method integrates multiple perceptions on supply chain operations and outlines a path to attain group consensus using a sample of 80 experts. The authors develop a meta-model, (the supply chain maturity model) that describes supply chain maturity at five levels across multiple competency areas. A maturity model for the evaluation of supply chain operations and definition of road-maps in Mexican firms is constructed for the purpose.

While exploratory research involves investigation into a problem where little or no information exists or where there are few or no earlier studies to serve as reference, it remains a fact-finding approach.

3.3. Identification and analysis of gaps

A framework on the general knowledge of SCM and SCOR concepts was employed for the identification of the assessment criteria. Despite our interest in reviewing articles that integrated environmental considerations, the search yielded only 5 environment-based and 11 return process-based papers. The review observes that the authors handled both empirical and hypothetical issues in the manufacturing industry, most of which were centred on the financial efficiency of supply chains.

3.3.1: Definition and analysis of gap assessment criteria elements

A number of assessment criteria were used to evaluate the different papers. Three different categories were applied for the assessment and included the following: general information, SCOR characteristics and the application information. Table 3.1 below summarizes the results of an assessment of the SCOR elements (Table 2.1) that were used.

Table 3.1: Summary of assessment results

Category	Criteria	Number of appearances in the papers
General Information	Inter-temporal dimension	Strategic: 16 Tactical: 8 Operational: 16
	Spatial dimension	Facilities: 13 Warehouse: 1 Vendors: 5 Clients: 5
	Functional dimension	Processing: 16; Manufacturing: 19; Distribution: 18; Sales: 3
SCOR Characteristics	Processes	Plan: 24; Source: 30; Make: 24; Deliver: 24; Return: 11
	Performance Attributes	Reliability: 18; Responsiveness: 21; Agility: 17; Cost: 18; Asset Management: 13
	Metric Level	Level 1: 29 Level 2: 22 Level 3: 13 Level 4: 4
	Process Types	Plan: 18 Execution: 16 Enable: 6
	Supply chain strategy	MTS: 21 MTO: 23 ETO: 12
	Practices	Best Practices: 9; Leading Practices: 1
	Return	Application method specified : 4; Application method not specified : 7
	SCOR version	V_1: 2; V_2: 0; V_3: 2; V_4: 3; V_5: 6; V_6: 4; V_7: 8; V_8: 6; V_9: 6
Application Information	Modeling Software and technology	ALPHA, e-SCOR, ARENA, MATLAB, Oracle e-Business suite, SAP, i2Technologies, Manugistics, People soft, Manhattan Associates, IBS, IDEFO, ARIS, XML, UDDI, WSDL, SIMPROCESS, Supply chain collaborator, SCOR-COS OWL, SCORmark, Choquet integral operator and Dempster Shafer Engine 1.0
	Industry sector	Services, IT, Thin film transistor, Automotive, Construction, Steel production, Transport, Public utility, Manufacturing, Tourism, Cement manufacturing, Jewellery, Furniture, Rubber, Tobacco, Retail, Graphics, Mining, Forestry Communication, Distribution, Telecommunications equipment, Rail construction, Electronics, Textile, Snow making factory production, Recycling and Aeronautics.

Table 3.1 shows that the authors expressed interest in various SCOR assessment elements. The papers applied eight SCOR model versions and 22 toolkits in 28 industry sectors. The study establishes time as an important variant in SCM where three supply chain dimensions (inter-temporal, spatial and functional dimensions) were applied in the papers.

The review also reveals that within the inter-temporal dimension, strategic and operational issues interested researchers more than tactical issues. Likewise, procurement, manufacturing and distribution appeared more important than sales, customer and logistics within the functional dimension, while facilities and clients were more important than warehouse and vendors within the spatial dimension. The inter-temporal dimension papers were made-up of 35.5% strategic decision level papers, 17.7% tactical decision level papers and 35.5% operational decision level papers. The spatial dimension papers comprised of the following: facilities (28.8%), vendors (11.1%), warehouse (2.2%) and clients (17.7%). The functional dimension papers were dominated by manufacturing (42.2%), procurement (35.5%), distribution planning (40%) and sales (6.6%), thus indication that the manufacturing and procurement functions are as well more important. All these variations could be accounted for by author preference or the link between each assessment element and the supply chain problem that was being investigated.

All 5 SCOR processes, the 5 performance attributes, 3 process types and 4 metric levels were applied by the various authors. Another assessment criterion of interest was the supply chain strategy (Table 3.1). By supply chain strategy, we mean the decoupling point that is chosen by a management team and which is determined by the type of customer demands and the cost effectiveness of the strategy on the operational components of the chain. Three supply chain strategies: Make-To-Stock (MTS), Make-To-Order (MTO) and Engineer-To-Order (ETO) were applied. 48.9% of the papers dealt with MTS, 55.6% with MTO and 31.1% with ETO supply chain strategy while 8.8% discussed more than one supply chain strategy (Hybrid case). Figure 3.1 illustrates the percentage distribution of articles by supply chain strategy.

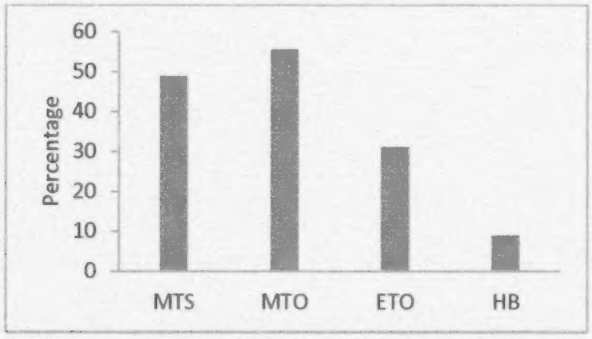

Fig. 3.1: Percentage distribution of articles by supply chain strategy

The increase in the number of MTO papers is evocative of the importance of the agile manufacturing design and the need to reduce inventory and waste along the supply chain. The papers applied eight SCOR model versions and 22 toolkits in 28 industry sectors.

3.3.2. Gap analysis journal, methodology and year of publication

The papers were published in 32 journals, giving a mean distribution of 1.4 articles per journal. Out of the 45 papers that were reviewed, 5 were published by the International Journal of Production Economics, giving a percentage representation of 11.11 for the journal. Figure 3.2 illustrates a pairwise comparison of journals in relation to the number of articles published.

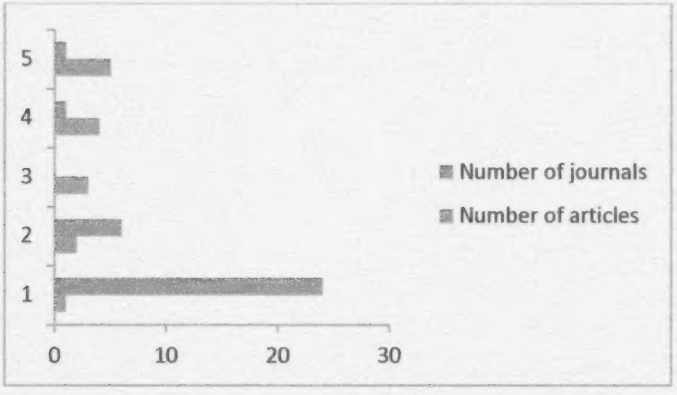

Fig. 3.2: Article distribution by journal

Figure 3.2 above indicates that of the 32 journals that were identified, 24 had just a single paper each, 6 had two each, 1 had four papers and one had five papers, giving a total of 45. A total of six methodological approaches were employed by the authors to attend their objectives.

Conceptual papers with statistical procedures dominated the list. Although most papers made significant contributions to supply chain performance, no single paper treated the three SCOR components (The Process Modelling factor, Performance Measurement and Best Practices) and the five management processes of Plan, Source, Make, Deliver and Return except Stephens (2001) who presents the first publication on the development and application of the template. The review also divulges that SCOR research is mostly centred on hypothetical issues (Fig. 3.3), which reduces its strategic importance in supply chain management. A synthesis of the methodologies applied is presented in Fig. 3.2 below.

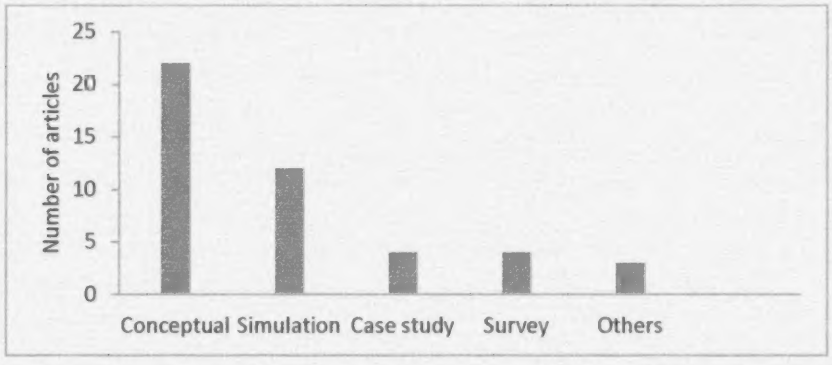

Fig. 3.3: Article distribution by research methodological approach

The research methodologies provided solutions to simple and complex supply chain problems. Out of the 45 papers, conceptual articles dominated the search with 22 (48.88%) articles followed by 12 (26.66%) simulation-based papers, 4 (8.88%) survey articles, 4 (8.88%) case studies, 3 (6.66%) exploratory and Delphi method papers. The study notes that researchers of the SCOR model are yet to show interest in case study, survey, exploratory and Delphi research methods. However, the articles can be characterised by subgroups and by themes such as general trends in SCOR model research, modelling methodologies, SCOR model evaluation and experiential applications.

No articles published in 2000 and 2002 were selected because those available did not meet the three selection criteria described under section 2.2. In the last decade and particularly after the review of the SCOR model by Huan *et al.*, (2004), results show a growing interest in the use of the model and an increase in the number of application papers (Fig. 3.4) with a stabilization (5-8 papers per year) from 2008.

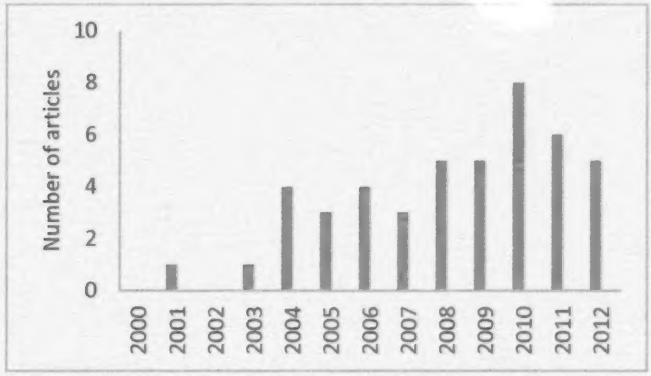

Fig. 3.4: Article distribution by year of publication

3.3.3. Gap analysis based on environmental considerations and the return process

In spite of the emphasis that we proposed on articles integrating environmental issues, papers linking the SCOR model with the environment were comparatively limited. Barely 11% of the papers discussed issues related to the environmental dimension of the model (Fig. 3.5) while about 24 % discussed the return process. The first author that attempted the environmental dimension of the SCOR model was in 2009. Subsequently, 2 papers each were published in 2010 and 2012 respectively. Only 2 papers attempted the return process between 2001 and 2006 while the other 9 were published between 2008 and 2012.

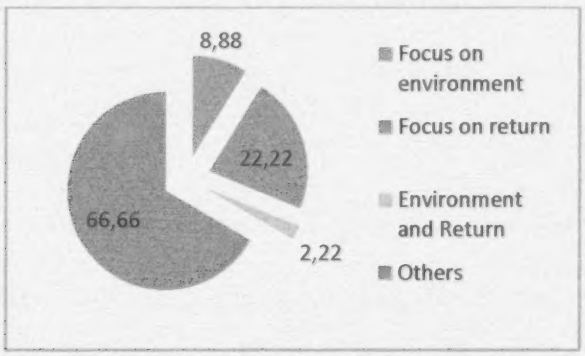

Fig. 3.5: Distribution of environment related and return papers

This limited interest in the environmental component of the model could imply that the environment was not the main focus of researchers. It could also be attributed to the generic form of the present GreenSCOR model, which describes environmental elements from a macro perspective, such as the carbon footprint.

Generally, the method of application of the return process by the authors can be classified under the following four headings: simple indication, process description, simulation and case study application). Figure 3.6 below illustrates the distribution of the papers based on the four approaches above.

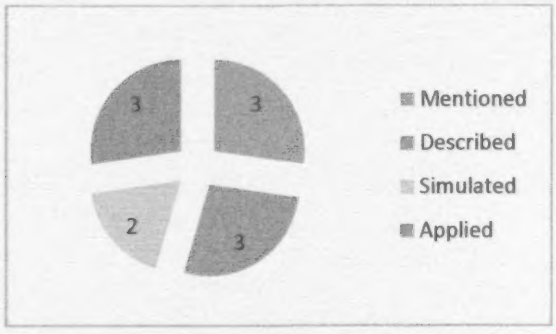

Fig. 3.6: How the return process is used in the papers

Out of the 11 papers that discussed the return process, 3 simply mentioned the process, 3 others presented a descriptive analysis, 2 simulated and 3 attempted a practical application. The review however reveals that although some authors discussed the environmental dimension and the return process of the SCOR model, they were not motivated by environmental concerns but by the cost implications of the supply chain. While the application of the return process is relatively restricted, an upward trend in the number of academic breakthroughs in eco-cycle operations such as Seuring (2004) is expected. With increasing competition and the need for supply chain environmental performance, there is need for the integration of the return process with traditional forward logistics chains.

3.3.4. Gap analysis by SCOR component

Authors showed varied interests in the different SCOR components and implementation levels. Figure 3.7 illustrates article distribution by SCOR component applied. The process modelling (ProM) factor was investigated in 34 (75.5%) papers.

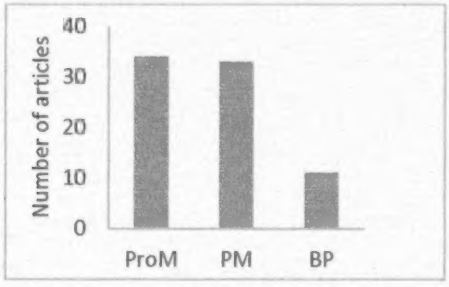

Fig. 3.7: Article distribution by SCOR component

However, the investigations were simply description-based or just application without modification. The performance measurement (PM) component was treated in 33 (73.3%) papers. The five attributes of the performance measurement component were applied in the following order: 19 (42.2%), 23 (51%), 21 (46.6%), 19 (42.2%) and 14 (31%) for reliability, responsiveness, agility, cost and asset management respectively. Finally, the Best Practices (BP) section was discussed in 11 (24.4%) papers

3.3.5. Gap analysis by SCOR management process

Although most organizations have embraced the innovative paradigm of moving from individual firms to supply chains as the means for creating value, no single paper experimented the SCOR model on an end-to-end supply chain approach. Fig. 3.8 illustrates article distribution by the SCOR management processes that were investigated.

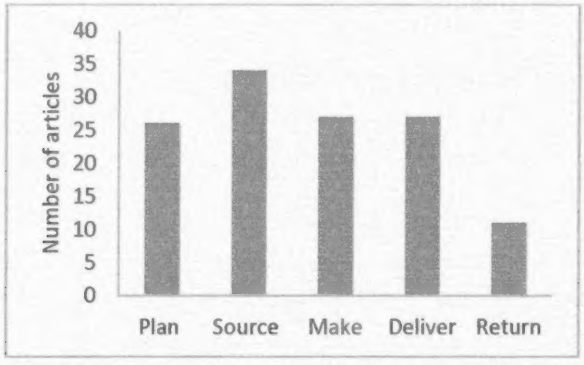

Fig. 3.8: Article distribution by SCOR management process

Out of the five management processes reviewed, the *Source* process interested the majority of authors with 34 (75.5%) application papers followed by the *Make* and *Deliver* processes with

27 (60%) papers each, 26 (58%) for the Plan process and 11 (24%) papers for the *Return* process. The focus of papers (Hwang *et al.*, 2008; Hwang *et al.*, 2010; Potthast *et al.*, 2010) on the sourcing component is likely due to its strategic upstream role in supply chain performance management.

4. Conclusion

This paper reviews selected application papers of the SCOR modelling framework in the Supply Chain Management literature between 2000 and 2012. We focused on providing information that could contribute to the improvement of the model, particularly its GreenSCOR component. Despite our interest in reviewing articles that integrated environmental considerations, our search yielded only 11.1% of environment related papers and 24.4% of papers that handled the return process. Six methodologies were applied by authors to attain the varied objectives that ranged from hypothetical to empirical applications of the template. The scientific contributions of the papers were presented and research gaps associated with the application identified. While a generally timid interest in the model was observed, annual distribution of the articles showed a positive trend in the number of environment and return process related papers. Where green aspects were considered, they were apparently motivated by the financial performance of supply chains and not by environmental concerns. The review demonstrates that the SCOR template is a useful tool for SCM. However, we observed that authors did not express interest in exploratory, case study and survey research. The study notes that while the SCOR model is suitable for supply chain financial performance evaluation, it is also a practical decision support tool for the environmental assessment of qualitative factors and competing decision alternatives along the chain. Given on-going concerns with climate change and the need for integration of green practices in industrial processes, the use of a close-loop supply chain operationalization approach in future studies would be expedient, particularly in industries and regions with important environmental impacts. Such experimentation shall contribute to the usefulness and generalized application of the SCOR model. A literature review of professional papers or a survey of industrial companies shall further expound the practicality of the model and its suitability as a scientific reference in the supply chain arena.

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